LA-UR-21-29452
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Title: External Release of Organic Scintillator DRiFT Software - Technology Evaluation and Demonstration Project Accomplishments

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Intended for: Report

Issued: 2021-09-24

Los Alamos NATIONAL LABORATORY

External Release of Organic Scintillator DRiFT Software Technology Evaluation and Demonstration Project Accomplishments

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September 24, 2021

Overview and Objectives

- DRiFT post processes radiation transport output from MCNP, and ***generates realistic nuclear instrumentation response***.

- Organic scintillator response has been developed, tested, and validated with measurements, these instruments are widely used in nuclear safeguards.

- At the beginning of this project, DRiFT was only available to LANL employees with access to yellow High Performance Computing clusters.
  - Additionally, there are many complicated external software dependencies

- Our TED project request proposed using funds to:
  - Comment and clean up code, friendly testing, ***generating test suites and examples***
  - Expansion of scintillator types natively supported by DRiFT
  - ***External release of DRiFT*** accompanied by ***documentation***

- We accomplished all objectives (and many others), they are highlighted in these slides.
  - A significant portion of this work was performed by Austin Mullen, a 2021 Keepin Nonproliferation Summer school participant and XCP-7 Graduate Research Assistant.

DETECTOR PHYSICS

- Natively supported scintillator, PMT, and digitizer models
- New pulse shape capability
- Ability for users to define their own instrumentation response.

DOCUMENTATION

- Manual describing detector physics, test suites, and diagnostics features of DRiFT
- README for obtaining and installing DRiFT executable

DIAGNOSTICS

- Flagging pile-up, cross talk, room return and other relevant features, (developed for a separate FY21 MFR project, however incorporated in the release).

ADVERTISEMENT

- Release of DRiFT manual (with LA-UR) externally (ResearchGate)
- Submission of paper for consideration by Journal of Nuclear Material Management (paper in RASSTI)
- Email to colleagues in NEN, P, XCP describing DRiFT capabilities.

EXTERNAL DRiFT RELEASE

SOFTWARE ENHANCEMENTS

- Test suites, unit tests and examples
- Incorporating code enhancements into exe

END USER LISCENCE AGREEMENT

LINUX OS EXECUTABLE

- Removal of all HPC and external dependencies.
- Statically linking necessary libraries.
- Install/use instructions
- Friendly testing at LANL prior to release

After Release:

Interested External User:

- Contacts DRiFT lead
- Once approved by FCI, DRiFT leads can release code directly to user.

Expansion of Scintillator and PMT Physics Options

- Before this project, only one PMT and scintillator type were natively supported by DRiFT.
  - To add a new detector or PMT the user would need to modify source code.

- **Scintillator and PMT types supported natively by DRiFT were expanded to 17 and 13 instrument models respectively.**

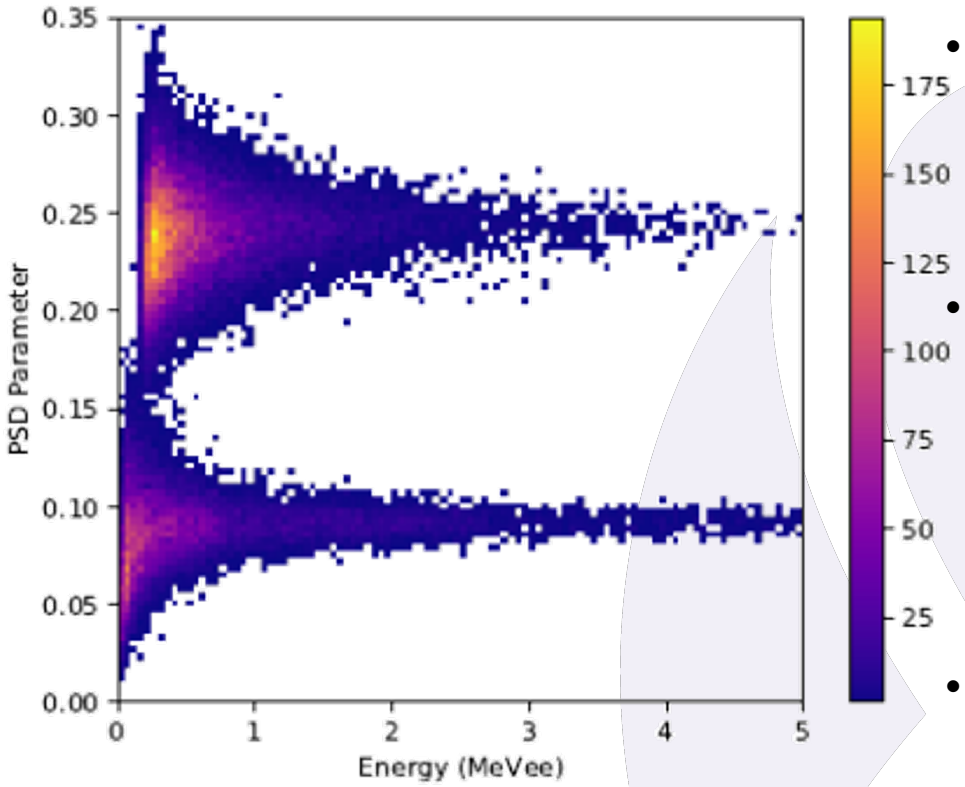
- Additionally, the **user can now add their own response** without modifying source code.
  - The release contains instructions and examples.

- **7 natively supported digitizers**, relevant to nuclear safeguards instrumentation were added
  - This saves the user from having track down technical specifications including resolution, termination resistance, sampling rates etc.

Name	Keywords	Options
[Scintillation]		
	call	Scintillation
	detector	*Scintillator name, ej. EJ301*
	optical_transport	*double, default 0.6*
	voltage	*double, 1500 V, PMT voltage*
	pmt_type	*PMT name, i.e. 9821B*
	max_energy	*double, 25.0 MeV default*
	gain	*double, default set by PMT voltage and model*
	scint_yield	*double, default set by scintillator type*
	PE_file	*filename of scintillator emission spectrum*
	QE_file	*filename of PMT quantum efficiency spectrum*
	light_file	*filename of scintillator light output table*
	pulse_shape_file	*filename of user-defined pulse shape*
	rise_time	*double, rise time of the scintillator (in ns) for pulse shape*
	decay_fast	*double, fast decay time constant (in ns) for pulse shape*
	decay_slow	*double, slow decay time constant (in ns) for pulse shape*
	fast_decay_weight	*double, relative weight of fast decay time constant*
	pulse_arrival_time	*double, default 15 ns*

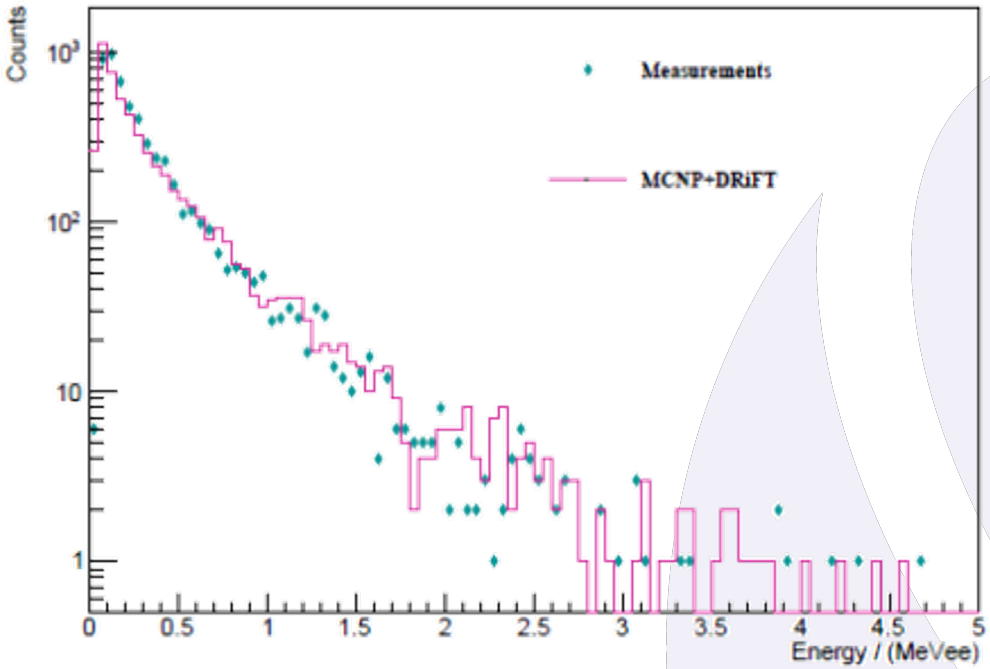
Name	Keywords	Options
[Digitizer]		
	call	Digitizer
	digitizer_samples	*int, 512*
	resolution	*int, 16384 default*
	voltage_range	*double, 2.0 V default*
	ter_res	*double, 50.0 ohm default*
	DC_offset	*double, 0.1 % default*
	start_point	*double, 0.1 by default*
	trigger_ADC	*int, 100 by default*
	rate	*double, 500.e6 default (Hz)*
	s_gate	*double, 22 e-9 by default (22 ns)*
	l_gate	*double, 90e-9 by default (90 ns)*
	PSD	*string, no by default*
	pileup	*string, no by default*
	digitizer_type	*string, none specified by default*

Accommodating User Defined Pulse Shapes



- One of the key useful and unique features of DRiFT is the ability to simulate digitizer electronic effects and pulses.
- Simulated pulse shapes have a wide variety of options from testing pulse shape discrimination (PSD) analysis to generating testing data for machine learning algorithms.
- Previously, only pulse shapes for EJ-301 scintillators were available.
- ***The code was expanded to accommodate user-defined pulses***. An example of a PSD plot produced with this option is shown above.
- Users can define pulse shapes two ways: analytic equations or with an example measured pulse as drift input

Generating Test Suites, Examples, and Unit Tests



- 2 existing test suites were cleaned up, and documented.
- **5 new test suites** / examples were added for the release.
- **Nuclear safeguards relevant examples** include: correlated fission measurements, pile-up, cross talk, source activities, and comparisons of DRiFT with measurements (shown on left)

- **Unit tests were developed to test code functionality** upon installation.
- The 3 unit tests are automatically executed at the end of the installation process, and compare the output of various internal DRiFT functions against archived "truth" values generating using pre-determined inputs.

Release: Approval from FCI

- Worked with FCI to:
  - Ensure we had permissions for an external release from all DRiFT sponsors.
  - Discuss the pathways for release, i.e. source code on GitHub (as originally proposed) or another form of release

- The FCI preferred and **approved a non-commercial end-user license agreement**.

- Interested users contact the developers who forward the request to FCI for review

- Approved users then receive DRiFT from leads (Madison Andrews or Cameron Bates)

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Executing DRiFT version 1.0.0 - Scintillator Exectutable Release

Please direct comments and questions to: Madison Andrews, madison@lanl.gov

Authors: Madison Andrews, Cameron Bates, Edward McKigney,
Austin Mullen, Surafel Woldegiorgis, Avneet Sood, Matthew Marcath

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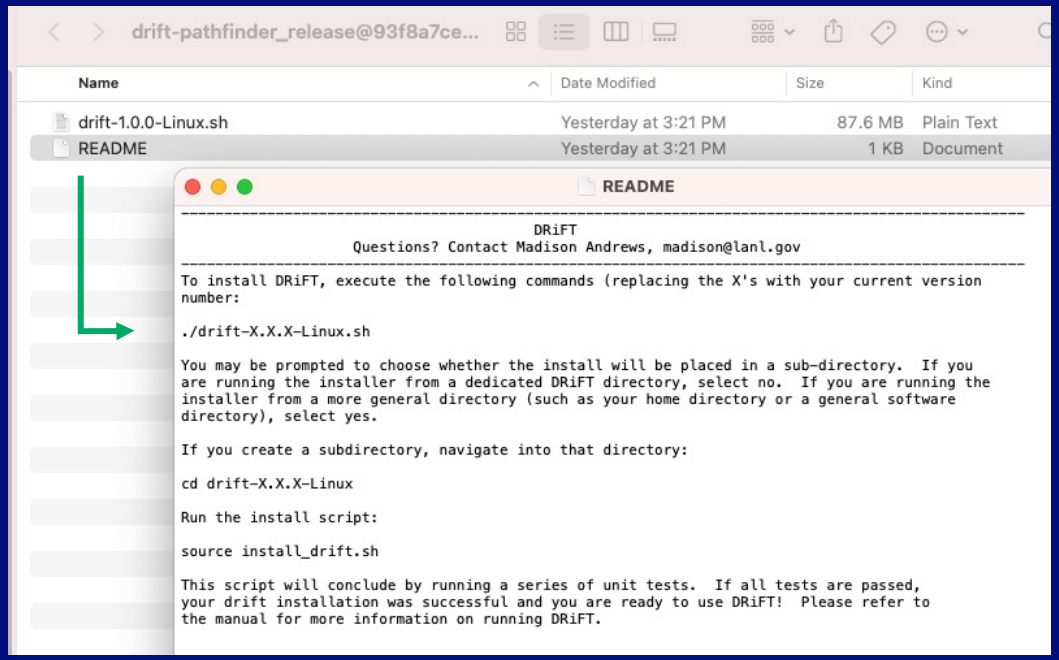
Release – Creating a DRiFT Installer



- A DRiFT executable installer is now available to approved requesters.
- It contains the installer (drift-1.0.0-Linux.sh) and a README file with simple installation instructions for the user.

- In order to generate a Linux executable:
  - DRiFT dependencies on LANL's HPC cluster, ROOT, Garfield++ and MCNPTools builds were removed.
  - CPACK was used to generate a STGZ self-extracting installer
  - Remaining dependencies (HDF5 and GCC libraries) were statically linked
- The release contains 7 test suites / examples in addition to 3 unit tests.
  - The unit tests are automatically executed at the end of the install process, and compare the output of various internal DRiFT functions against archived values.

Documentation – Manual

DRiFT - RELEASE 1.0.0
ORGANIC SCINTILLATORS

DRiFT Contributors:

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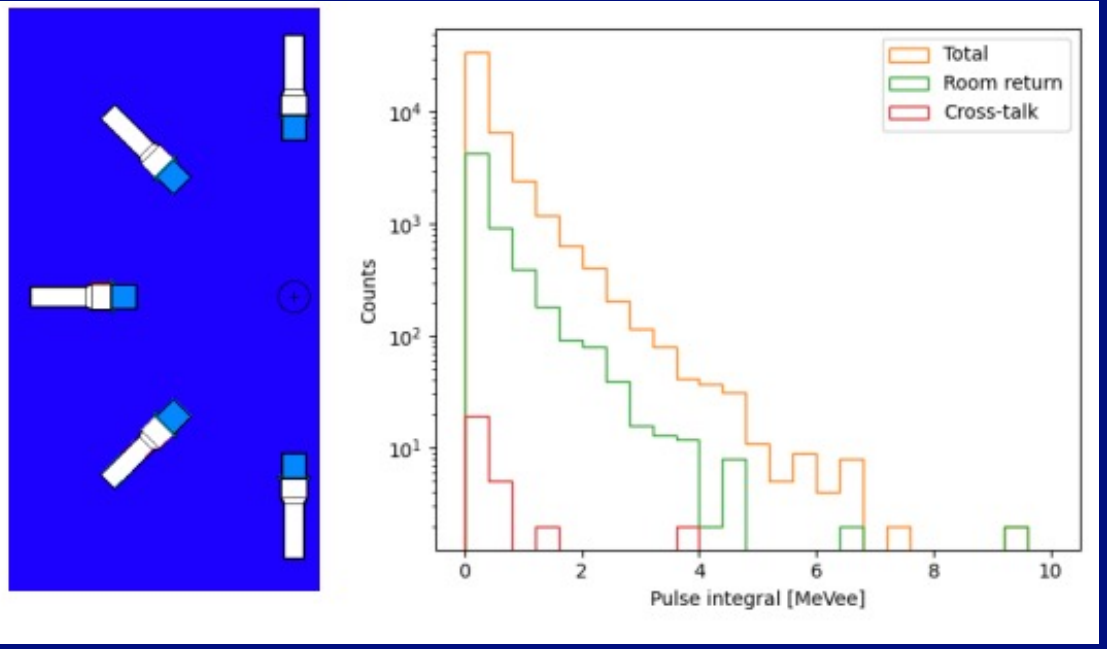
Last Updated: September 17, 2021
Los Alamos National Laboratory Technical Report
LA-UR-21-29114

- Detailed 65 page manual was created with TED funds to accompany the DRiFT executable.
- The manual contains 12 chapters split into 4 parts:
  - DRiFT Overview
  - Detector Physics – Scintillators
  - Additional DRiFT Features
  - Test Suites and Examples
- DRiFT executable and manual have been used by a friendly tester in nuclear safeguards in Q4 of FY21.

Documentation: Full Paper



- M.T. Andrews, A. Mullen, S. Woldegiorgis, M.E. Rising, "A DRiFT Organic Scintillator Executable for Nuclear Safeguards Applications"

- Currently in RASSTI awaiting LA-UR assignment.

- We describe DRiFT capabilities available in the executable.

- Focus on features, examples and instrument relevant to nuclear safeguards and non proliferation.

- Will submit to Journal of Nuclear Materials Management for their consideration once we receive an unlimited release number.
  - This journal will reach our target audience, nuclear safeguards professionals.

Conclusions

- A DRiFT executable has been generated for Linux OS and approved by FCI for release.

- We expanded DRiFT scintillator simulation capabilities from a single scintillator and PMT proof of concept to natively supporting many scintillator, PMT, and digitizer models relevant to current and proposed nuclear safeguards instrumentation.
  - Users can also add their own custom instrument response and define pulse shapes.
  - A manual describing installation, DRiFT use, and examples accompanies the release.

- In the future, the helium-3 gas detector capabilities developed as part of a FY21 should be released in a similar manner.

Acknowledgements

- This work was supported by Laboratory Technology Evaluation & Demonstration Funding
  - Diagnostic features in DRiFT that were also included with the release were developed with LDRD MFR funds in FY21

- We also appreciate the executable testing and feedback in FY21 performed by David Broughton in NEN-1.

References

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